pletely arrested for a time or merely temporarily slackened (ralentie), and he gives the results of some new experiments on seeds maintained at from – 37° C. to – 53° C. in the "snow-box" of a refrigerating machine for a period of 118 days. Most of the seeds resisted this treatment successfully, and the author concludes that after a sufficient interval of time has elapsed the protoplasm of the ripe seed passes into a state of complete inertness in which it is incapable either of respiration or assimilation, and that whilst in this condition it can support, without detriment to its subsequent revival, rapid and considerable lowering of temperature.

De Candolle then points out that if it really be a fact that the suspended life of a resting seed is in any way dependent on respiration we might expect this to be shown by submitting seeds to a barometric vacuum for some time. He does not appear to have followed out this suggestion, and is apparently unaware of the direct experiments on this point carried out by Romanes two years previously; he argues, however, that if ordinary respiration is a factor of any importance, this may be determined by immersing the seeds in mercury for such a length of time as to ensure the complete consumption of the small amount of oxygen contained within their tissues. It was found that when seeds of *wheat*, and of *Lepidium sativum* were thus treated, for periods varying from one to three months, their power of germination was not sensibly affected.

Although these last described experiments of C. de Candolle go far to show that any considerable amount of respiration is unnecessary for the maintenance of potential life in the protoplasm of resting seeds, they are not inconsistent with the view that some minute amount of gaseous exchange may be going on during the whole course of the experiment at the expense of the oxygen contained in the seeds at the time of immersion in the mercury. The results would have been far more conclusive on this point if it had been shown that the gaseous oxygen originally contained in the seed tissue had been completely used up in an early stage of the experiment. The experiments of Romanes, however, conducted with high vacua and atmospheres of various gases, leave no room for doubt on this question, and we must consequently abandon all idea of the dormant state of resting seeds having any necessary dependence whatever on ordinary respiratory processes. Neither set of experiments, however, excludes the possibility of molecular interchanges in the protoplasm itself, such molecular transpositions in fact as those which can often be induced in living cells placed under anaërobic conditions, and which are all exothermic in character, and generally, but not necessarily, attended with the liberation of more or less CO The great value of the low temperature experiments we have described lies in the fact that such processes of autoxidation, and in fact any conceivable internal chemical change in the protoplasts, are rendered impossible at temperatures of – 180° C. to – 190° C., and that we must consequently regard the protoplasm in resting seeds as existing in an absolutely inert state, devoid of any trace of metabolic activity, and yet conserving the potentiality of life. Such a state has been admirably compared by C. de Candolle with that of an explosive mixture, whose components can only react under determinate conditions of temperature; as long as these conditions remain unfulfilled the substances can remain in contact with each other for an indefinite period without combining.

It appears to us that the occurrence of a state of complete chemical inertness in protoplasm, without a necessary destruction of its potential activity, must necessitate some modification in the current ideas of the nature of life, for this inert state can scarcely be included in Mr. Herbert Spencer's well-known definition, which implies a continuous adjustment of internal to external relations.[1] The definition doubtless holds good for the ordinary *kinetic* state of protoplasm, but it is not sufficiently comprehensive to include protoplasm in the *static* condition in which it undoubtedly exists in resting seeds and spores. The definition becomes in fact one of "vital activity" rather than of life.

As it is inconceivable that the maintenance of "potential vitality" in seeds during the exposure of more than 100 hours to a temperature of – 180° to – 190° C. can be in any way conditioned by, or correlated with, even the feeblest continuance of metabolic activity, it becomes difficult to see why there should be any time-limit to the perfect stability of protoplasm when once it has attained the resting state, provided the low temperature is maintained; in other words an immortality of the individual protoplasts is conceivable, of quite a different kind from that potentiality for unending life which is manifested by the fission of unicellular organisms, and with which Weismann has rendered us familiar.

In what manner and to what extent "resting" protoplasm differs from ordinary protoplasm we do not at present know, but there are indications, notably those afforded by the resting state of desiccated Rotifera, and also by some recent experiments of Van Eyck on discontinuous germination ("Ann. Agron," vol. xxi. (1895), p. 236), that ordinary protoplasts may, by suitable treatment, be brought to the "resting" condition.

In 1871, Lord Kelvin, in his Presidential Address to the British Association, threw out the suggestion that the origin of life as we know it may have been extra-terrestrial, and due to the "moss-grown fragments from the ruins of another world," which reached the earth as meteorites.[1] That such fragments might circulate in the intense cold of space for a perfectly indefinite period without prejudice to their freight of seeds or spores, is almost certain from the facts we know about the maintenance of life by "resting" protoplasm; the difficulties in the way of accepting such a hypothesis certainly do not lie in this direction.

We must express our thanks to Mr. Thiselton-Dyer and to Dr. D. H. Scott, for the facilities they have given us in carrying out these experiments in the Jodrell Laboratory.

Addendum.

After the completion of the above Note, our attention was called to a recent investigation by M. R. Chodat, on the influence of low temperatures on *Mucor mucedo* ("Bulletin de l'Herbier Boisier," vol. iv. (1896), p. 894). He found that a lowering of temperature for several hours to – 70° to – 110° C. failed to kill young spores of the mucor, and he adduces certain evidence, which is not, however, wholly convincing, that even the mycelium itself, when cultivated on Agar Agar, and whilst in active growth, is able to resist the action of these low temperatures. The author sums up his opinion as to the bearing of his experiments on the nature of life in the following words:—"La respiration elle-même est évidemment complètement arrêtée à cette température où les corps chimiques ne réagissent plus les uns sur les autres. Si l'on considère que la vie consiste principalement en un échange continuel de substance, soit par la nutrition intracellulaire, soit par la respiration, alors il faut convenir qu'à ces temperatures basses la vie n'existe plus. C'est une fatale erreur qu'on rencontre dans presque tous les traités que la respiration est une condition nécessaire de la vie, alors qu'elle n'est qu'une des conditions de sa manifestation. La vie est conditionée par certaines structures. Les forces qui les mettent en jeu peuvent être des forces toutes physiques. Elles sont simplement les sources d'énergie qui pourront mettre la machine en mouvement."

THE LAW OF CONDENSATION OF STEAM.

AT the meeting of the Institution of Civil Engineers on Tuesday, November 30, an important paper was read on "The Law of Condensation of Steam," by Prof. Hugh L. Callendar, F.R.S., and John T. Nicolson.

In the discussion of steam-engine trials it had generally been assumed that the rate of condensation of steam on a surface was practically infinite, so that any surface in direct contact with the steam was immediately heated to the saturation temperature corresponding with the pressure of the steam. It had also been supposed that the amount of condensation under any given conditions was limited, either by the resistance of the film of condensed water to the passage of heat, or by the capacity of the

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[1] The following passage from the "First Principles" (Section 25) clearly shows that the author in constructing his definition had not anticipated the possibility of a *living* organism attaining a state of absolutely stable equilibrium. "All vital actions, considered not separately but in their *ensemble*, have for their final purpose the balancing of certain outer processes by certain inner processes. There are unceasing external forces tending to bring the matter of which organic bodies consist into that state of stable equilibrium displayed by inorganic bodies; there are internal forces by which this tendency is constantly antagonised, and the perpetual changes which constitute life may be regarded as incidental to the maintenance of the antagonism."

[1] We find that Prof. Dewar called attention in one of his Royal Institution lectures in 1892 to the bearing of his low temperature experiments with spores, &c., on this suggestion of Lord Kelvin's (see *Roy. Inst. Proc.*, 1892, vol. xiii. p. 699.)

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metal or of the circulating water to carry off the heat. In many cases condensation was diminished by films of oil or grease, or by accumulations of hair, or by other incrustations or deposits, but these were not considered in the paper.

The authors found, on the contrary, as the result of their experiments on a steam-engine running under normal conditions, that a practically clean and dry metal surface was not immediately heated to the temperature of the saturated steam in contact with it, that the rate of condensation of steam was not infinite, but finite and measurable, and that the amount of condensation in any given case was limited chiefly by this finite rate of condensation, and could be calculated in terms of it.

The cyclical variations of temperature in the metallic walls of the cylinder, with each stroke of the engine, were measured by means of thermo-couples inserted at various distances from the inner surface. It was possible thus to deduce the amount of heat absorbed and given out by the metal, and to infer the quantity of steam condensed and re-evaporated at different points of the stroke. The temperature-cycles of the steam were simultaneously measured by a very sensitive platinum thermometer. The observations showed that the temperature of the steam in different parts of the cylinder differed in a systematic way from the saturation temperature as deduced from indicator diagrams.

In order to deduce the condensation from the observed temperature-cycles, it was necessary to determine the conductivity and specific heat of cast iron. A series of experiments were made upon a four-inch bar of cast iron, and the result found for the conductivity was nearly 30 per cent. smaller than that generally assumed.

At the lowest speed of the experiments, namely, forty-five revolutions per minute, the temperature of the surface of the metal at the end of the admission period was found to be never raised higher than within 20° F. of the temperature of the steam, and the rate of condensation at any moment was simply proportional to the difference between the temperature of the steam and the surface. The numerical value found for the rate of condensation was 0·74 B.T.U. per second per square foot of surface per degree Fahrenheit of difference between the temperature of the steam and the surface. This was equivalent to the condensation of 27 pounds of steam per square foot per hour at 300° F., for a difference of temperature of 10° F. Assuming this law, the total amount of condensation at any point of the stroke could be inferred by measuring the "Condensation Areas" on the temperature-cycle diagram, *i.e.* the areas included between the curves representing the temperatures of the steam and of the metal surface.

To compare the results thus found with the missing steam deduced from the indicator diagrams and the feed measurements, the leakage of the valve and piston was determined as nearly as possible under the conditions of running. It was found to be proportional to the difference of pressure and nearly independent of the speed through a considerable range. The usual test for leakage with the valve stationary was found to be of little or no value. From a comparison of leakage tests, it was inferred that a valve in motion, however well fitted, was subject to leakage of a definite type. The leakage took place chiefly in the form of water, by condensation and re-evaporation on the moving surfaces, and was directly proportional to the perimeter of the ports and inversely to the width of the bearing surfaces. The amount of condensation observed during the admission period in a single-acting non-condensing cylinder 10·5 inches in diameter with a stroke of 12 inches, was only 20 per cent. of the feed at a speed of 100 revolutions per minute. The smallness of this result was probably due to the early compression and the dryness of the steam supply. It was found that re-evaporation was completed very quickly, and that the walls were dry for the greater part of the cycle. It was inferred from the form of the temperature curves and from other evidence that the rate of re-evaporation was the same as that of condensation.

From the form of the law of condensation it was possible to make an important theoretical deduction with regard to cases in which re-evaporation was incomplete, and the walls remained wet throughout the whole cycle. Under these conditions the mean temperature of the walls should be the same as the time average of the temperature of the steam to which they were exposed, and the cyclical condensation was the maximum possible for the given steam cycle. If the extent of the clearance surfaces was known, this limiting value of the condensation in any case might be easily deduced from the indicator diagram. If the surfaces were dry during part of the stroke, the condensation was less than the limit, and it was necessary to know the mean temperature of the clearance surfaces in addition. Upon these views of the nature of condensation and leakage, the missing quantity of steam W in pounds per hour might be expressed by an equation of the general type, $W = S\,(t' - t^{\circ}) + L\,(p' - p'')$,—where the first term represented condensation and the second term leakage, S being the equivalent clearance surface in square feet, and $t' - t^{\circ}$ the mean difference of temperature, in degrees Fahrenheit, between the walls and the steam during admission reduced to one-half cut-off. L, the rate of leakage per pound difference of pressure $p' - p''$, might be taken to vary approximately as the product of the diameter and the square root of the normal piston-speed, for engines of different sizes. It would appear from this formula that the effect of leakage on the performance was relatively more important in small engines and at high pressures, and that the loss due to condensation was most effectively reduced by increase of piston-speed.

As an indirect verification of this law of condensation, the temperature of the clearance surface in cases in which water was present in the cylinder was measured, and was found to agree with that of the mean of the steam cycle. The amount of condensation was also correctly calculated in several cases of published tests in which sufficient data were available. The rate of condensation deduced was also directly verified by an entirely different method. The experiments gave approximately the same rate of condensation, and appeared to show that the water-drops condensed on the metallic surface, owing probably to their rapid action, did not appreciably diminish the rate. Assuming it possible to estimate the condensation occurring in any given case by the method indicated, from a knowledge of the indicator diagram and of the temperature and area of the clearance surfaces, it then became possible to determine the amount of leakage under the actual conditions of running.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The Institution of Civil Engineers has resolved to exempt Bachelors of Arts who obtain honours in the Mechanical Sciences Tripos from the examination prescribed for the Associate Membership of the Institution.

The Managers of the John Lucas Walker Studentship have elected Mr. J. W. W. Stephens, of Caius College, to the studentship in Pathology, and Dr. Hamilton K. Wright, of McGill University, Montreal, to an Exhibition of the value of 50*l.*

The proposal to authorise the Examiners for the Natural Sciences Tripos Part II. to inspect the laboratory note-books of candidates for honours was carried in the Senate by forty-seven votes to eighteen.

Dr. H. A. Giles has been elected to the Professorship of Chinese. Dr. W. H. R. Rivers, of St. John's College, has been appointed University Lecturer in Physiological and Experimental Psychology. Mr. W. L. H. Duckworth, Fellow of Jesus College, has been recognised as a Lecturer in Anthropology.

The Walsingham Medals for research in Biology, including Physiology, have been awarded to Mr. V. H. Blackman, of St. John's College, and Mr. W. M. Fletcher, of Trinity College. The electors report that the essays of four other candidates were of a high order of merit.

The election to the Isaac Newton Studentship in Astronomical Physics will be held in the Lent Term 1898. Candidates must be Bachelors of Arts of less than twenty-five years of age on January 1. The studentship is of the value of 200*l.* a year for three years. Applications are to be sent to the Vice-Chancellor between January 14 and 24.

The University delegates to the International Congress of Hygiene at Madrid, next April, are Dr. Kanthack, Dr. D. MacAlister, and Dr. Anningson.

THE death is announced of Dr. Brownless, Chancellor of Melbourne University.

DR. H. H. HOFFERT has been promoted to a senior inspectorship under the Science and Art Department, and Mr. S. J. Cartlidge—at present head-master of the Hanley School of Art—has been appointed to the vacant inspectorship.

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